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Empirical experiments on the nature of Swiss mountains

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1. Introduction and aims

Issues related to the nature of the existence (or not) of mountains and the difficulties of defining the extent of such *fiat objects*, are well known in the philosophical and GIScience literatures. Smith and Mark (2003) point out that such a question has profound practical implications, since many users of GIS conceptualise space by dividing it into distinct objects whilst working with data which are best represented by fields. As a trivial example, consider the question of "what are the average gradients found on the Matterhorn?" The first part of the question requires us to define gradient, which can be calculated across different scales and using a variety of different models of our continuous surface and algorithms to extract the magnitude of the first derivative of the terrain surface. The second part of the question, and the focus of this paper, requires that we define the extend of the Matterhorn.

Fisher et al. (2004) addressed this issue by comparing the landforms (and in particular peaks) identified by multi-scale morphometric analysis with a toponym database for the English lake district. Ontological research has shown that mountains are one of the most commonly reported forms of "natural earth formations" (Battig and Montague, 1968 in Mark et al., 1999) and taken empirical approaches to deriving information about *geographic objects,* defined as being bounded spatial objects consisting of parts which may be complex (Mark et al., 1999). In gathering information about the nature of geographic objects a range of questions can be considered. For example, what terms are associated with a given geographic object, how can the boundaries of such objects be defined, and what are typical attributes of a geographic attribute.

In this paper we report on ongoing work aimed at further investigating the question of "What is a mountain" through a mixture of empirical investigations, data mining and morphological analysis. Here we report on the empirical part of the work, where our aim is to gather information that we can apply in morphological analysis.

2. Methodology

Since it has been found in previous work (e.g. Mark and Turk, 2003) that categories associated with geographic objects differ for people from different locations and cultures, our study focused on a group of subjects from similar backgrounds (Swiss geography students) and investigated only mountains in a Swiss context.

The study was carried out through a questionnaire, delivered over the internet, which subjects could complete in their own time. To control for bias occurring as result of question order, four versions of the questionnaire, differing only in terms of question order, were prepared. On starting the questionnaire, subjects were randomly allocated one of the four possible versions of the questionnaire. The questionnaire contained a total of 17 questions, of which 2 were open format (i.e. the users could type a response) and the rest closed format (i.e. the user selected a possible value from a list).

The questions could be divided into categories related to terms, attributes and boundaries. Terms associated with mountains were collected through an open question, where users were simply asked to enter up to three terms that they associated with mountains.

Data about the following attributes were collected: height; slope; tree line; influence of civilisation, dominance and prominence, where dominance relates to the distance to neighbouring peaks and prominence to the difference in altitude between neighbouring peaks. Height values were collected through an open question, with the remaining attributes being closed questions where the users were asked to select a value from a range associated with some form of illustration. To compare the effects of differing types of illustration, users were presented with illustrations in three forms: schematic sketches, 3D visualizations generated from Google Earth and photographs. Figure 1 shows a typical question, in this case for prominence illustrated in the three ways described above. For each question, users are asked to select from a range of values lying between 1 (not a mountain) to 7 (clearly an individual mountain) based on the following question: “How ‘mountain-like’ is object A?”

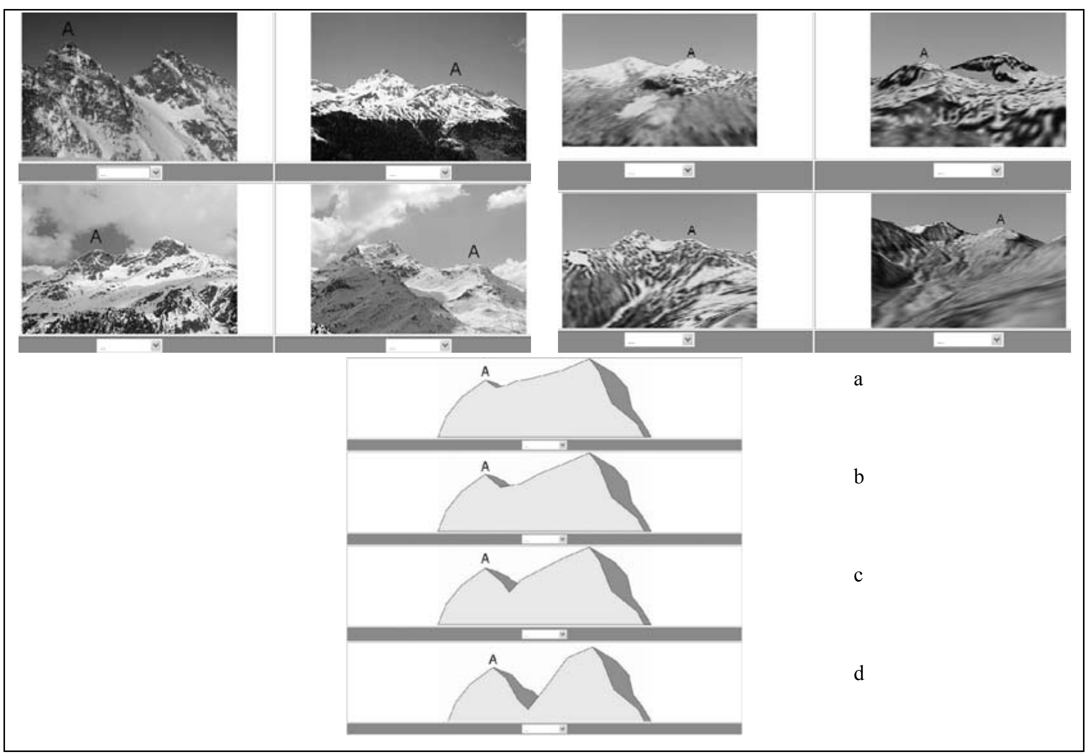

Figure 1: Example of attribute question for prominence, using photograph, 3D visualisation and schematic illustration. Results for schematic illustration are illustrated in Figure 3.

Finally, a set of questions investigating the boundaries of individual mountains, all based on the use of photographs were posed, where subjects were asked to select a single photograph which best described the boundaries of an individual mountain.

3. Results

The questionnaire was completed by 61 subjects. Of these 61, ~85% originate from the main urban regions of Switzerland (the "Mittelland"), some 10% in the Alps and the remaining 5% from outside Switzerland. Table 1 shows the terms which more than one subject associated with mountains.

Hoch (high)	20	Steinbock (ibex)	2
Fels (rock)	17	Sonne (sun)	2
Schnee (snow)	17	Spitze (peak)	2
Steil (steep)	15	Wandern (hiking)	8
Natur (nature)	7	Snowboarden (snowboarding)	3
Aussicht (view)	6	Klettern (climbing)	3
Mächtig (huge)	6	Freizeit (leisure)	2
Alpen (alps)	4	Ski (skiing)	2
Gipfel (summit)	4	Bergsteigen (mounaineering)	2
Stein (stone)	4	Matterhorn	4
Eis (ice)	2	Schweiz	3
Gletscher (glacier)	2	Eiger	2
Massiv (massive)	2		

Table 1: Terms associated with mountains

Figure 2 illustrates the height values chosen by subjects as being the minimum height of a Swiss mountain, where the mean was 1364m with a standard deviation of ± 713m.

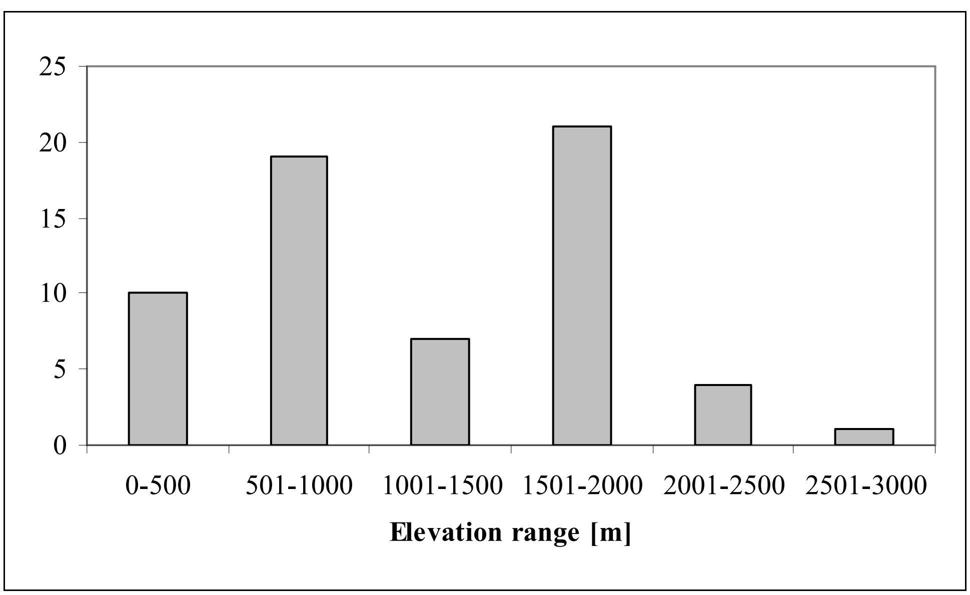

Figure 2: Distribution of representative Swiss mountain heights

Figure 3 shows a set of illustrative results for the schematic illustration of prominence in Figure 1.

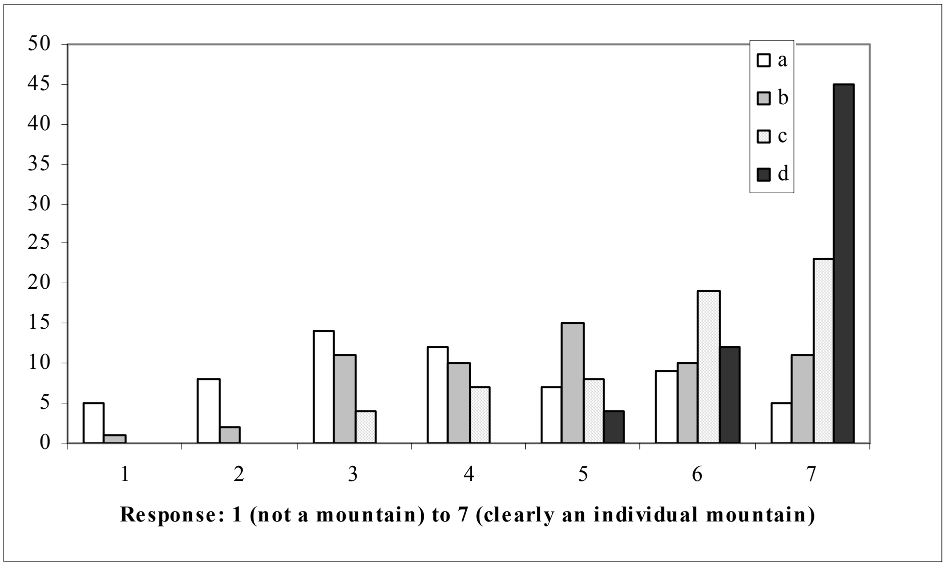

Figure 3: Responses to the question, how mountain like is this picture for the schematic illustrations in Figure 1

Table 2 shows, for each attribute, firstly whether the subjects' responses to different questions produce statistically significantly different distributions, and secondly whether the attribute values are correlated (e.g. is there a relationship between prominence and the degree to which an image is considered "mountain-like").

Attribute	Visualisation type	Schematic	3D Visualisation	Photograph
Prominence	Friedman Test	$p<0.001$	$p<0.001$	$p<0.001$
	Spearman Correlation	$r^2=0.62$	$r^2=0.45$	$r^2=0.20$
Dominance	Friedman Test	$p<0.001$	-	$p<0.001$
	Spearman Correlation	$r^2=0.42$	-	$r^2=0.17$
Slope	Friedman Test	-	$p<0.001$	$p<0.001$
	Spearman Correlation	-	$r^2=0.35$	$r^2=0.45$
Civilisation	Friedman Test	-	-	$p<0.001$, $p < 0.001$
	Spearman Correlation	-	-	$r^2=0.21$, $r^2=0.12$
Tree line	Friedman Test	$p<0.001$	-	$p<0.001$, $p < 0.001$
	Spearman Correlation	$r^2=0.52$	-	$r^2=0.17$

Table 2: Significance testing for results of question distributions and correlations between attribute values (non-parametric tests)

For the case of selecting the boundary of an individual mountain, in all 3 cases the majority of our subjects simply selected the largest possible extent given as an option.

4. Discussion

We are still in the preliminary stages of analysing the large dataset collected in this work, but several interesting observations are possible. Firstly, a wide range of terms were used to describe mountains, but those occurring most often all described attributes of the mountain itself rather than activities or locations (e.g. high, rock, snow and steep).

Secondly, the range of heights suggested as defining a Swiss mountain was very broad, with conspicuous peaks in values of 1000m and 2000m. Furthermore, the standard deviation in elevation (700m) describes some 20% of the total variation in elevation in Switzerland. Thus, our results show clearly that elevation is not a useful descriptor of Swiss mountains.

Thirdly, our results show that the attributes chosen do go some way to allowing us to characterise mountains, with statistically significant answer distributions for different representations of the attributes tested. Furthermore, correlation values based on ranks for each question show relatively strong correlations (r^2~0.5-0.6) for prominence and tree line and slightly weaker correlations for slope and dominance. The relationship between the anthropogenic objects in the images is on the other hand weak. Also noteworthy is that correlation values are in general higher for the more abstract representations than for photographs. This suggests that other properties of the image come into play in these representations – for example, in photographs the subjects use objects in the scene (e.g. trees) to estimate the size of the mountain, and apply this as a discriminating factor rather than simply the variable under investigation (e.g. dominance). This result has some resonance with the work of Smallman and St. John (2005), who suggest that when presented with more realistic displays users often underperform and that simplification and caricaturing task relevant elements of a representation (as in Figure 1c) is likely to improve performance.

We are currently working on applying these results to extract the degree of "mountainousness" of different regions in the Swiss Alps by applying the relationships extracted from our empirical studies to Digital Elevation Models.

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